(19) Europäisches Patentamt
European Patent Office
Office européen des brev ts

(11) Publication number: 0 077 998
A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 82109647.6

(22) Date of filing: 19.10.82

(51) Int. Cl.³: C 08 F 216/14
C 08 F 218/18

(30) Priority: 22.10.81 JP 169748/81

(43) Date of publication of application: 04.05.83 Bulletin 83/18

(84) Designated Contracting States: DE FR GB IT

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(54) Fluorine-containing elastomeric copolymers, and their production.

(57) A fluorine-containing elastomeric copolymer which comprises units of at least one of fluorovinyl ethers of the formula:

$$XO\left(CFYCF_2O\right)_nCF=CF_2$$

wherein X is C_1-C_3 perfluoroalkyl, C_1-C_3 ω-hydroperfluoroalkyl or C_1-C_3 ω-chloroperfluoroalkyl, Y is hydrogen, chlorine, fluorine, trifluoromethyl, difluoromethyl or chlorodifluoromethyl and n is an integer of 1 to 4 and units of at least one of other fluorine-containing monomers copolymerizable therewith, the content of the fluorovinyl ether units being 15 to 50 mol%, and has an excellent resistance to low temperatures.

EP 0 077 998 A2

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FLUORINE-CONTAINING ELASTOMERIC COPOLYMERS, AND THEIR PRODUCTION

The present invention relates to fluorine-containing elastomeric copolymers, and their production. More particularly, it relates to fluorine-containing elastomeric copolymers comprising units of fluorovinyl ethers and having excellent resitance to low temperatures, and their production.

Ethylene-propylene rubbers (hereinafter referred to as "EPDM") are known to be excellent in resistance to low temperatures. It is also known that the substitution of the hydrogen atoms in EPDM with fluorine atoms results in improvement of resistance to heat and chemicals. Examples of such fluorine-substituted polymers are vinylidene fluoride/hexafluoropropylene copolymer, propylene/tetrafluoroethylene copolymer, etc. However, these fluorine-substituted polymers are inferior to EPDM in resistance to low temperatures and cause various problems when used in cold places.

In order to improve the said drawbacks of fluorine-substituted polymers, it has been proposed to blend them with silicone rubber, followed by covulcanization. In this case, however, silicone rubber is required to be used as a major component, and as the result, advantageous properties inherent to fluorine-substituted polymers themselves are more or less lost. It has also been proposed

to incorporate suitable plasticizers into fluorine-substituted polymers, but separation of the plasticizers is frequently caused depending upon the circumstances.

On the other hand, attempt has been made to synthesize perfluoropolyethers having ether linkages in the backbone chain by ionic polymerization of perfluoroolefinic epoxides. In this case, the increase of the content of ether linkages makes the glass transition temperature of the resulting polymer lower. But, polymers of high molecular weight and elasticity are hardly obtainable. Attempt has also been made to produce polymers having ether linkages in the side chains, for instance, by copolymerization of vinylidene fluoride or tetrafluoroethylene with a monomeric compound of the formula: $CF_2=CFOR_f$ (wherein R_f is CF_3, C_2F_5 or C_3F_7). The resulting copolymers are elastomeric, but their glass transition temperatures can be not sufficiently lowered even when the content of vinyl ether units is much increased.

As a result of the extensive study, it has now been found that copolymers of fluorovinyl ethers having a plural number of ether linkages and other monomers copolymerzable therewith, which contains the units of the fluorovinyl ethers in a certain amount or more show sufficiently lowered glass transtion temperatures and excellent resistance to low temperatures.

According to the present invention, at least one of fluorovinyl ethers of the formula:

$$XO\!\left(CFYCF_2O\right)_nCF=CF_2 \qquad [I]$$

wherein X is C_1-C_3 perfluoroalkyl, C_1-C_3 ω-hydroperfluoroalkyl or C_1-C_3 ω-chloroperfluoroalkyl, Y is hydrogen, chlorine, fluorine, trifluoromethyl, difluoromethyl or chlorodifluoromethyl and n is an integer of 1 to 4, and at least one of other fluorine-containing monomers copolymerzable therewith are polymerized, preferably in the presence of a polymerization initiating source, to give a fluororine-containing elastomeric copolymer having units of the fluorovinyl ether(s) in an amount of 15 to 50 mol%.

Because the fluorine-containing elastomeric copolymer of the invention contains at least two ether linkages in a side chain, its glass transition temperature is effectively lowered and its low temperature properties are greatly improved.

Hitherto, it is known that the polymerization of a fluoromonomer (e.g. tetrafluoroethylene, chlorotrifluoroethylene, vinyl fluoride) with a fluorovinyl ether of the formula: $X'CF_2CF_2O(CFX'CF_2O)_mCF=CF_2$ (wherein X' is fluorine, chlorine, hydrogen, difluoromethyl, chlorodifluoromethyl or perfluoromethyl and m is an integer of not less 1) affords a copolymer having units of the fluorovinyl ether in an amount of 1 to 3 % by weight (Japanese Patent Publication (examined) No. 18340/1967). In this case, a small amount of the fluorovinyl ether is used for improvement of the physical properties (e.g. lowering of the melt viscosity) of the polymer comprising the fluoromonomer. However, the

incorporation of units of any fluorovinyl ether into any polymer in such a large amount as used in the present invention for the purpose of improvement of low temperature resistance has never been known.

Among the fluorovinyl ethers [I], preferred are perfluorovinyl ethers. They can be prepared, for instance, from perfluoropropylene oxide according to the following scheme:

$$\underset{\diagdown\!O\!\diagup}{CF_3CF{-}CF_2} \xrightarrow[\text{diglyme}]{KF} CF_3CF_2CF_2O(\underset{|}{\overset{CF_3}{|}}\!\!\!\!CFCF_2O)_n\overset{CF_3}{\overset{|}{C}}FCFO$$

$$\Big\downarrow \text{Thermal decomposition}$$

$$CF_3CF_2CF_2O(\overset{CF_3}{\overset{|}{C}}FCF_2O)_nCF{=}CF_2$$

In the formula [I] for the fluorovinyl ethers, n is required to be an integer of 1 to 4. When it is larger than 4, such fluorovinyl ether can be isolated and/or purified with great difficulty. Further, its contribution to the enhancement of the low temperature resistance becomes lower. Still, the fluorovinyl ether may be used alone or in combination. In other words, a mixture of the fluorovinyl ethers having different n values may be used.

As the other fluorine-containing monomers, there may employed tetrafluoroethylene, trifluoroethylene, chlorotrifluoroethylene, vinylidene fluoride, vinyl fluoride, etc.

Polymerization is to be carried out so that the content of the fluorovinyl ether unit in the produced copolymer becomes from 15 to 50 mol%. When the content is

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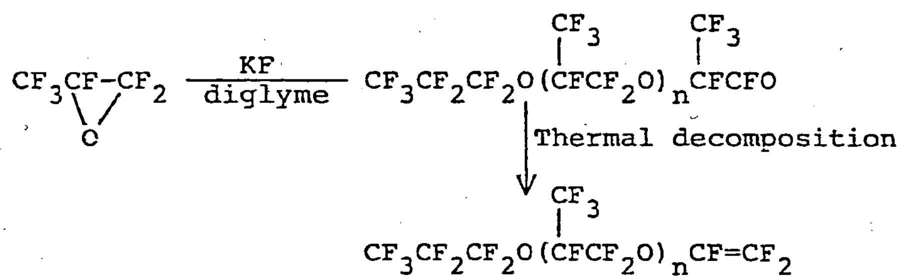

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Polymerization is to be carried out so that the content of the fluorovinyl ether unit in the produced copolymer becomes from 15 to 50 mol%. When the content is

less than 15 mol%, the copolymer loses the elastomeric property and is much deteriorated in low temperature resistance.

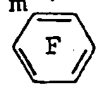
For the polymerization, various modes such as bulk polymerization, suspension polymerization, solution polymerization or emulsion polymerization may be adopted. In case of solution polymerization, there may be used various solvents such as dichlorofluoromethane, trichlorofluoromethane, chlorodifluoromethane, 1,1,2-trichoro-1,2,2-trifluoroethane (hereinafter referred to as "R-113"), 1,2-dichloro-1,1,2,2-tetrafluoroethane, 1,1,2,2-tetrachloro-1,2-difluoroethane, perfluorocyclobutane and perfluorodimethylcyclobutane. Among them, the one having a higher fluorine substitution is favorable. In case of bulk polymerization, suspension polymerization or solution polymerization, organic initiators are normally employed. Preferred organic initiators are highly fluorinated peroxides, especially diacyl peroxides of the formula: $(R_f\text{-COO})_2$ (wherein R_f is perfluoroalkyl, ω-hydroperfluoroalkyl or perchlorofluoroalkyl. In case of emulsion polymerization, the use of a water or oil-soluble peroxide in the presence of a perfluorinated emulsifier may be preferred.

The regulation of the molecular weight of the copolymer to be produced may be acheived by controlling the relationship between the polymerization rate and the amount of the initiator, more preferably by the incorporation of a chain transfer agent into the reaction system. The chain

transfer agent may be suitably selected depending upon the kinds of the fluorovinyl ethers [I] and of the other monomers. Specific examples are hydrocarbons of 4 to 6 carbon atoms, alcohols, ethers, organic halides (e.g. CCl_4, $CBrCl_3$, $CF_2BrCFBrCF_3$, CF_2I_2), etc. When an iodinated fluorocarbon such as CF_2I_2, $I(CF_2)_4I$ or $CF_2=CFCF_2CF_2I$ is employed as the chain transfer agent, the iodine atoms bonded to the terminal positions of the copolymer molecules remain in a radically active state so that the resulting copolymer can be advantageously vulcanized with a peroxide as the radical source in the presence of a polyfunctional unsaturated compound such as triallyl isocyanurate or triallyl cyanurate.

The polymerization temperature may be determined by the decomposition temperature of the initiator. The polymerization pressure may be determined by the kind of the other fluorine-containing monomer copolymerizable with the fluorovinyl ether [I]. Thus, those reaction conditions may be appropriately determined by the copolymerization ratio of the starting monomers so as to attain the desired content of the fluorovinyl ether units in the produced copolymer.

On vulcanization of the produced copolymer, an appropriate vulcanization procedure should be chosen depending on the kind of the other fluorine-containing monomer copolymerzable with the fluorovinyl ether [I]. When, for instance, the other fluorine-containing monomer is vinylidene fluoride, trifluoroethylene or vinyl fluoride, the vulcaniz-

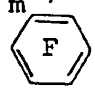
ation may be carried out with polyamine alone or an aromatic polyol-vulcanization accelerator system. When the other fluorine-containing monomer is tetrafluoroethylene or chlorotrifluoroethylene, the said vulcanization system is hardly usable, and the incorporation of a monomer having a vulcanizable site will become necessary. Examples of the monomer having a vulcanizable site are $CF_2=CFO(CF_2)_mCN$, $CF_2=CFO(CF_2)_mBr$, $CF_2=CFO(CF_2)_mI$, $CF_2=CFOCF_2CF_2Cl$, $CF_2=CFCF_2COOH$, $CF_2=CFO(CF_2)_m$  (wherein m is an integer of 1 to 8), etc. In case of a iodinated or brominated fluorocarbon being used as the chain transfer agent in the polymerization, the vulcanization with a peroxide is applicable as stated above.

The fluorine-containing elastomeric copolymer has not only a resistance to heat, chemicals and oils as good as a perfluoroolefin resin but also elasticity at low temperature.

The present invention will be further explained in detail by the following Examples and Comparative Examples.

Examples 1 and 2 and Comparative Example 1

Into a pressure resistant glass made ampoule of 60 ml volume equipped with a valve, a fluorovinyl ether of the formula: $CF_2=CF(OCF_2CF(CF_3))_2OC_3F_7$ (hereinafter referred to as "ψ_3VE") in an amount as shown in Table 1 was charged, and a solution of 1,3,5-trichloroperfluorohexanoyl peroxide in R-113 (0.4 g/ml) (0.2 g) was added thereto. The atmosphere in the ampoule was replaced by a comonomer as shown in Table

ation may be carried out with polyamine alone or an aromatic polyol-vulcanization accelerator system. When the other fluorine-containing monomer is tetrafluoroethylene or chlorotrifluoroethylene, the said vulcanization system is hardly usable, and the incorporation of a monomer having a vulcanizable site will become necessary. Examples of the monomer having a vulcanizable site are $CF_2=CFO(CF_2)_mCN$, $CF_2=CFO(CF_2)_mBr$, $CF_2=CFO(CF_2)_mI$, $CF_2=CFOCF_2CF_2Cl$, $CF_2=CFCF_2COOH$, $CF_2=CFO(CF_2)_m$  (wherein m is an integer of 1 to 8), etc. In case of a iodinated or brominated fluorocarbon being used as the chain transfer agent in the polymerization, the vulcanization with a peroxide is applicable as stated above.

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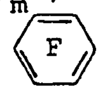
ation may be carried out with polyamine alone or an aromatic polyol-vulcanization accelerator system. When the other fluorine-containing monomer is tetrafluoroethylene or chlorotrifluoroethylene, the said vulcanization system is hardly usable, and the incorporation of a monomer having a vulcanizable site will become necessary. Examples of the monomer having a vulcanizable site are CF_2=CFO$(CF_2)_m$CN, CF_2=CFO$(CF_2)_m$Br, CF_2=CFO$(CF_2)_m$I, CF_2=$CFOCF_2CF_2Cl$, CF_2=$CFCF_2COOH$, CF_2=CFO$(CF_2)_m$  (wherein m is an integer of 1 to 8), etc. In case of a iodinated or brominated fluorocarbon being used as the chain transfer agent in the polymerization, the vulcanization with a peroxide is applicable as stated above.

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1. The pressure was adjusted as shown in Table 1. Then, the reaction was carried out at 15°C while shaking for a period of time as shown in Table 1. The ϕ_3VE-containing phase became fairly viscous. After completion of the reaction, R-113 (50 g) was added to the reaction mixture. To the resulting solution, acetone was added dropwise for fractionation with the molecular weight, and the precipitated copolymer was recovered. The fraction hardly soluble in R-113 was a soft rubber having a high molecular weight and a high viscosity. The substance soluble in R-113 was a liquid or solid elastomer having [η] (in R-113, at 20°C) = 0.1 to 0.4. The highest molecular weight fraction obtained from the R-113 solution by fractionation with acetone showed the physical properties as shown as in Table 2.

Table 1

	ϕ_3VE (g)	Comonomer	Pressure (kg/cm^2G)	Time (hour)	Yield (g)
Example 1	13.5	Tetrafluro-ethylene	1.5	96	7.3
Example 2	10.1	Vinylidene fluoride	2	6	7.2
Comparative Example 1	7.5	Tetrafluoro-ethylene	3.2	18	4.1

Table 2

	$[\eta]$ *1)	ϕ_3VE Content (mol%) *2)	Glass transition temperature (°C) *3)
Example 1	0.2	27	-32
Example 2	0.4	51	-44
Comparative Example 1	-	13	20

Notes: *1) measured in R-113 at 20°C;
*2) determined by elementary analysis;
*3) determined by DSC.

Comparative Example 2

In the same manner as in Example 1, $CF_2=CFOCF_3$ and tetrafluoroethylene were polymerized. The produced copolymer having units of $CF_2=CFOCF_3$ in a content of 35 mol% showed a glass transition temperature of -9°C.

In comparison of the produced copolymer with the copolymer obtained in Example 1, it is understood that remarkable depression of the glass transition temperature and improvement of low temperature resistance are attained in Example 1.

Example 3

Into a pressure resistant glass made ampoule as in Example 1, ϕ_3VE (10.1 g), a solution of 1,3,5-trichloroperfluorohexanoyl peroxide in R-113 (0.4 g/ml) (0.005 ml) and 1,4-diiodoperfluorobutane (0.005 ml) were charged, and the atmosphere in the amouple was replaced by tetrafluoroethylene. The pressure was raised to 1 kg/cm²G. Then, polymerization was initiated at 15°C while shaking. After

18 hours, the depression of a pressure of 0.2 kg/cm²G was observed. The said peroxide solution (0.0025 ml) was added to the reaction system, and the pressure was elevated with tetrafluoroethylene to a pressure of 1 kg/cm²G. After 24 hours, the pressure was again decreased by 0.4 kg/cm²G. The peroxide solution (0.0025 ml) was again added to the reaction system, and the pressure was elevated with tetrafluoroethylene to a pressure of 1 kg/cm²G. After 48 hours, the depression of a pressure of 0.4 kg/cm²G was observed. After the pressure was released, R-113 (50 ml) was added to the reaction mixture, followed by agitation. The contents were treated with a large amount of acetone to precipitate the copolymer. The copolymer was collected and dried under reduced pressure to obtain a solid copolymer (7.5 g). The elemental analysis showed a ϕ_3VE content of 32 mol%, and the glass transition temperature by DSC was -41°C.

The solid copolymer (2 g) was added to a solution of triallyl isocyanurate (0.1 g) and 2,5-dimethyl-2,5-di(t-butylperoxy)hexane (0.05 g) in R-113 (50 ml) and dispersed uniformly. The solvent was evaporated at 60°C. The residue was sandwiched with aluminum foils and pressurized at 160°C for 20 minutes. The resultant product was treated with 5N hydrochloric acid to dissolve the aluminum foils, whereby a colorless, transparent film was obtained. This film was not soluble in R-113 and had a sufficient mechanical strengh as the vulcanized rubber.

What is claimed is:

1. A fluorine-containing elastomeric copolymer which comprises units of at least one of fluorovinyl ethers of the formula:

$$XO(CFYCF_2O)_nCF=CF_2$$

wherein X is C_1-C_3 perfluoroalkyl, C_1-C_3 ω-hydroperfluoroalkyl or C_1-C_3 ω-chloroperfluoroalkyl, Y is hydrogen, chlorine, fluorine, trifluoromethyl, difluoromethyl or chlorodifluoromethyl and n is an integer of 1 to 4 and units of at least one of other fluorine-containing monomers copolymerizable therewith, the content of the fluorovinyl ether units being 15 to 50 mol%.

2. The copolymer according to claim 1, wherein the other fluorine-containing monomer(s) are chosen from tetrafluoroethylene, trifluoroethylene, chlorotrifluoroethylene, vinylidene fluoride and vinyl fluoride.

3. A process for preparing a fluorine-containing elastomeric copolymer which comprises polymerizing at least one of fluorovinyl ethers of the formula:

$$XO\text{-}(CFYCF_2O\text{-})_nCF=CF_2$$

wherein X is C_1-C_3 perfluoroalkyl, C_1-C_3 ω-hydroperfluoroalkyl or C_1-C_3 ω-chloroperfluoroalkyl, Y is hydrogen, chlorine, fluorine, trifluoromethyl, difluoromethyl or chlorodifluoromethyl and n is an integer of 1 to 4 with at

least one of other fluorine-containing monomers copolymerizable therewith to obtain a copolymer having units of the fluorovinyl ether in a content of 15 to 50 mol% is produced.

4. The process according to claim 3, wherein the polymerization is effected in the presence of a polymerization initiating source.

(19) Europäisches Patentamt
European Patent Office
Offic européen des brevets

(11) Publication number: **0 077 998**
B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication of patent specification: **22.06.88**

(51) Int. Cl.[4]: **C 08 F 216/14**, C 08 F 218/18

(21) Application number: **82109647.6**

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(45) Publication of the grant of the patent:
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(84) Designated Contracting States:
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(56) References cited:
DE-A-1 645 132
GB-A- 976 136

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In order to improve the said drawbacks of fluorine-substituted polymers, it has been proposed to blend them with silicone rubber, followed by convulcanization. In this case, however, silicone rubber is required to be used as a major component, and as the result, advantageous properties inherent to fluorine-substituted polymers themselves are more or less lost. It has also been proposed to incorporate suitable plasticizers into fluorine-substituted polymers, but separation of the plasticizers is frequently caused depending upon the circumstances.

On the other hand, attempt has been made to synthesize perfluoropolyethers having ether linkages in the backbone chain by ionic polymerization of perfluoroolefinic epoxides. In this case, the increase of the content of ether linkages makes the glass transition temperature of the resulting polymer lower. But, polymers of high molecular weight and elasticity are hardly obtainable. Attempt has also been made to produce polymers having ether linkages in the side chains, for instance, by copolymerization of vinylidene fluoride or tetrafluoroethylene with a monomeric compound of the formula: $CF_2{=}CFOR_f$ (wherein R_f is CF_3, C_2F_5 pr C_3F_7). The resulting copolymers are elastomeric, but their glass transition temperatures can be not sufficiently lowered even when the content of vinyl ether units is much increased.

As a result of the extensive study, it has now been found that copolymers of fluorovinyl ethers having a plural number of ether linkages and other monomers copolymerizable therewith, which contains the units of the fluorovinyl ethers in a certain amount or more show sufficiently lowered glass transition temperatures and excellent resistance to low temperatures.

According to the present invention, at least one of fluorovinyl ethers of the formula:

$$XO{+}CFYCF_2O{\not{)}}_n CF{=}CF_2 \qquad [I]$$

wherein X is C_1—C_3 perfluoroalkyl, C_1—C_3 ω-hydroperfluoroalkyl, or C_1—C_3 ω-chloroperfluoroalkyl, Y is hydrogen, chlorine, fluorine, trifluoromethyl, difluoromethyl or chlorodifluoromethyl and n is an integer of 1 to 4, and at least one of another fluorine-containing monomers copolymerizable therewith are polymerized, preferably in the presence of a polymerization initiating source, to give a fluorine-containing elastomeric copolymer having units of the fluorovinyl ether(s) in an amount of 15 to 50 mol%.

Because the fluorine-containing elastomeric copolymer of the invention contains at least two ether linkages in a side chain, its glass transition temperature is effectively lowered and its low temperature properties are greatly improved.

Hitherto, it is known that the polymerization of a fluoromonomer (e.g. tetrafluoroethylene, chlorotrifluoroethylene, vinyl fluoride) with a fluorovinyl ether of the formula: $X'CF_2CF_2O(CFX'CF_2O)_mCF{=}CF_2$ (wherein X' is fluorine, chlorine, hydrogen, difluoromethyl, chlorodifluoromethyl or or perfluoromethyl and m is an integer of not less than 1) affords a copolymer having units of the fluorovinyl ether in an amount of 1 to 3% by weight (Japanese Patent Publication (examined) No. 18340/1967). In this case, a small amount of the fluorovinyl ether is used for improvement of the physical properties (e.g. lowering of the melt viscosity) of the polymer comprising the fluoromonomer. However, the incorporation of units of any fluorovinyl ether into any polymer in such a large amount as used in the present invention for the purpose of improvement of low temperature resistance has never been known.

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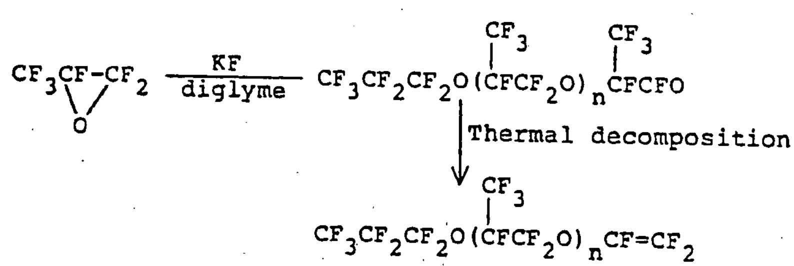

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Polymerization is to be carried out so that the content of the fluorovinyl ether unit in the produced copolymer becomes from 15 to 50 mol%. When the content is less than 15 mol%, the copolymer loses the elastomeric property and is much deteriorated in low temperature resistance.

For the polymerization, various modes such as bulk polymerization, suspension polymerization, solution polymerization or emulsion polymerization may be adopted. In case of solution polymerization, there may be used various solvents such as dichlorofluoromethane, trichlorofluoromethane, chlorodifluoromethane, 1,1,2-trichloro-1,2,2-trifluoroethane (hereinafter referred to as "R—113"), 1,2-dichloro-1,1,2,2-tetrafluoroethane, 1,1,2,2-tretrachloro-1,2-difluoroethane, perfluorocyclobutane and perfluorodimethylcyclobutane. Among them, the one having a higher fluorine substitution is favourable. In case of bulk polymerization, suspension polymerization or solution polymerization, organic initiators are normally employed. Preferred organic initiators are highly fluorinated peroxides, especially diacyl peroxides of the formula: $(R_f—COO)_2$ (wherein R_f is perfluoroalkyl, ω-hydroperfluoroalkyl or perchlorofluoroalkyl. In case of emulsion polymerization, the use of a water or oil-soluble peroxide in the presence of a perfluorinated emulsifier may be preferred.

The regulation of the molecular weight of the copolymer to be produced may be achieved by controlling the relationship between the polymerization rate and the amount of the initiator, more preferably by the incorporation of a chain transfer agent into the reaction system. The chain transfer agent may be suitably selected depending upon the kinds of the fluorovinyl ethers (I) and of the other monomers. Specific examples are hydrocarbons of 4 to 6 carbon atoms, alcohols, ethers, organic halides (e.g. CCl_4, $CBrCl_3$, $CF_2BrCFBrCF_3$, CF_2I_2), etc. When the iodinated fluorocarbon such as CF_2I_2, $I(CF_2)_4I$ or $CF_2{=}CFCF_2CF_2I$ is employed as the chain transfer agent, the iodine atoms bonded to the terminal positions of the copolymer molecules remain in a radically active state so that the resulting copolymer can be advantageously vulcanized with a peroxide as the radical source in the presence of a polyfunctional unsaturated compound such as triallyl isocyanurate or triallyl cyanurate.

The polymerization temperature may be determined by the decomposition temperature of the initiator. The polymerization pressure may be determined by the kind of the other fluorine-containing monomer copolymerizable with the fluorovinyl ether (I). Thus, those reaction conditions may be appropriately determined by the copolymerization ratio of the starting monomers so as to attain the desired content of the fluorovinyl ether units in the produced copolymer.

On vulcanization of the produced copolymer, an appropriate vulcanization procedure should be chosen depending on the kind of the other fluorine-containing monomer copolymerizable with the fluorovinyl ether (I). When, for instance, the other fluorine-containing monomer is trifluoroethylene or vinyl fluoride, the vulcanization may be carried out with polyamine alone or an aromatic poly-vulcanization accelerator system. When the other fluorine-containing monomer is tetrafluororethylene or chlorotrifluoroethylene, the said vulcanization system is hardly usable, and the incorporation of a monomer having a vulcanizable site will become necessary. Examples of the monomer having a vulcanizable site are $CF_2{=}CFO(CF_2)_mCN$, $CF_2{=}CFO(CF_2)_mBr$, $CF_2{=}CFO(CF_2)_mI$, $CF_2{=}CFOCF_2CF_2Cl$, $CF_2{=}CFCF_2COOH$, $CF_2{=}CFO(CF_2)_m$

(wherein m is an integer of 1 to 8), etc. In case of a iodinated or brominated fluorocarbon being used as the chain transfer agent in the polymerization, the vulcanization with a peroxide is application as stated above.

The fluorine-containing elastomeric copolymer has not only a resistance to heat, chemicals and oils as good as a perfluoroolefin resin but also elasticity at low temperature.

The present invention will be further explained in detail by the following Examples and Comparative Examples.

Examples 1 and 2 and Comparative Example 1

Into a pressure resistant glass made ampoule of 60 ml volume equipped with a valve, a fluorovinyl ether of the formula: $CF_2{=}CF(OCF_2CF(CF_3))_2OC_3F_7$ (hereinafter referred to as "ΦVE") in an amount as shown in Table 1 was charged, and a solution of 1,3,5-trichloroperfluorohexanoyl peroxide in R—113 (0.4 g/ml) was added thereto. The atmosphere in the ampoule was replaced by a comonomer as shown in Table 1. The pressure was adjusted as shown in Table 1. Then, the reaction was carried out at 15°C while shaking for a period of time as shown in Table 1. The Φ_3VE-containing phase became fairly viscous. After completion of the reaction R—113 (50 g) was added to the reaction mixture. To the resulting solution, acetone was added dropwise for fractionation with the molecular weight, and the precipitated copolymer was recovered. The fraction hardly soluble in R—113 was a soft rubber having a high molecular weight and

a high viscosity. The substance soluble in R—113 was a liquid or solid elastomer having [η] (in R—113, at 20°C)=0.1 to 0.4. The highest molecular weight fraction obtained from the R—113 solution by fractionation with acetone showed the physical properties as shown as in Table 2.

Table 1

	ϕ_3VE (g)	Comonomer	Pressure (kg/cm^2G) Pa	Time (hour)	Yield (g)
Example 1	13.5	Tetrafluro-ethylene	(1.5) 253313	96	7.3
Comparative Example 2	10.1	Vinylidene fluoride	(2) 303975	6	7.2
Comparative Example 1	7.5	Tetrafluoro-ethylene	(3.2) 425565	18	4.1

Table 2

	[η] *1)	ϕ_3VE Content (mol%) *2)	Glass transition temperature (°C) *3)
Example 1	0.2	27	-32
Comparative Example 2	0.4	51	-44
Comparative Example 1	-	13	20

Notes: *1) measured in R-113 at 20°C;
*2) determined by elementary analysis;
*3) determined by DSC.

Comparative Example 3

In the same manner as in Example 1, CF_2=$CFOCF_3$ and tetrafluoroethylene were polymerized. The produced copolymer having units of CF_2=$CFOCF_3$ in a content of 35 mol% showed a glass transition temperature of −9°C.

In comparison of the produced copolymer with the copolymer obtained in Example 1, it is understood that remarkable depression of the glass transition temperature and improvement of low temperature resistance are attained in Example 1.

Example 3

Into a pressure resistant glass made ampoule as in Example 1, Φ_3VE (10.1 g), a solution of 1,3,5-trichloroperfluorohexanoyl peroxide in R—113 (0.4 g/ml) (0.005 ml) and 1,4-diiodoperfluorobutane (0,005 ml) were charged, and the atmosphere in the ampoule was replaced by tetrafluoroethylene. The pressure was raised to 202650 Pa (1 kg/cm^2G). Then, polymerization was initiated at 15°C while shaking. After 18 hours, the depression of a pressure of 121590 Pa (0.2 kg/cm^2G) was observed. The said peroxide solution (0.0025 ml) was added to the reaction system, and the pressure was elevated with tetrafluoroethylene to a pressure of 202650 Pa (1 kg/cm^2G). After 24 hours, the pressure was again decreased by 141855 Pa (0.4 kg/cm^2G). The peroxide solution (0.0025 ml) was again added to the reaction system, and the pressure was elevated with tetrafluoroethylene to a pressure of 202650 Pa (1 kg/cm^2G). After 48 hours, the depression of a pressure of 141855 Pa (0.4 kg/cm^2G) was observed. After the pressure was released, R—113 (50 ml) was added to the reaction mixture, followed by agitation. The contents were treated with a large amount of acetone to precipitate the copolymer. The copolymer was collected and dried under reduced pressure to

obtain a solid copolymer (7.5 g). The elemental analysis showed a Φ_3VE content of 32 mol%, and the glass transition temperature by DSC was −41°C.

The solid copolymer (2 g) was added to a solution of triallyl isocyanurate (0.1 g) and 2,5-dimethyl-2,5-di(t-butylperoxy)hexane (0.05 g) in R—113 (50 ml) and dispersed uniformly. The solvent was evaporated at 60°C. The residue was sandwiched with aluminium foils and pressurized at 160°C for 20 minutes. The resultant product was treated with 5N hydrochloric acid to dissolve the aluminium foils, whereby a colorless, transparent film was obtained. This film was not soluble in R—113 and had a sufficient mechanical strength as the vulcanized rubber.

Claims

1. A fluorine-containing elastomeric copolymer which comprises units of at least one of fluorovinyl ethers of the formula:

$$XO(CFYCF_2O)_nCF=CF_2$$

wherein X is C_1—C_3 perfluoroalkyl, C_1—C_3 ω-hydroperfluoroalkyl or C_1—C_3 ω-chloroperfluoroalkyl, Y is hydrogen, chlorine, fluorine, trifluoromethyl, difluoromethyl or chlorodifluoromethyl and n is an integer of 1 to 4 and units of at least one of other fluorine-containing monomers chosen from tetrafluoroethylene, trifluoroethylene, chlorotrifluoroethylene and vinyl fluoride, the content of the fluorovinyl ether units being 15 to 50 mol%.

2. A process for preparing a fluoro-containing elastomeric copolymer according to claim 1 which comprises polymerizing at least one of fluorovinyl ethers with at least one of other fluorine-containing monomers.

3. The process according to claim 2, wherein the polymerization is effected in the presence of a polymerization initiating source.

Patentansprüche

1. Fluor enthaltendes elastomeres Copolymer, umfassend Einheiten wenigstens eines Fluorovinylethers der Formel

$$XO(CFYCF_2O)_nCF=CF_2$$

in der

X C_1—C_3-Perfluoroalkyl, C_1—C_3-ω-Hydroperfluoroalkyl oder C_1—C_3-ω-Chloroperfluoroalkyl ist,

Y Wasserstoff, Chlor, Fluor, Trifluoromethyl, Difluoromethyl oder Chlorodifluoromethyl ist und

n eine ganze Zahl von 1 bis 4 ist, und Einheiten wenigstens eines anderen, Fluor enthaltenden Monomers ausgewählt aus Tetrafluoroethylen, Trifluoroethylen, Chlorotrifluoroethylen und Vinylfluorid, wobei der Gehalt an Fluorovinylether-Einheiten 15 bis 50 Mol-% beträgt.

2. Verfahren zur Herstellung eines Fluor enthaltenden elastomeren Copolymers nach Anspruch 1, umfassend das Polymerisieren wenigstens eines Fluorovinylethers mit wenigstens einem anderen, Fluor enthaltenden Monomer.

3. Verfahren nach Anspruch 2, worin die Polymerisation in Gegenwart einer die Polymerization auslösenden Quelle bewirkt wird.

Revendications

1. Un copolymère élastomère contenant de fluor, qui comprend des motifs d'au moins un éther fluorovinylique de formula:

$$XO(CFYCF_2O)_nCF=CF_2$$

dans laquelle X représente un groupe perfluoralkyle en C_1—C_3, ω-hydroperfluoralkyle en C_1—C_3ou ω-chloroperfluoralkyle en C_1—C_3, Y représente l'hydrogène, le chlore, le fluor, un groupe trifluorométhyle, difluorométhyle ou chlorodifluorométhyle et n est un nombre allant de 1 à 4, et des motifs d'au moins un autre monomère contenant du fluor, choisi dans le groupe formé par le tétrafluoréthylène, le trifluoréthylène, le chlorotrifluoréthylène et le fluorure de vinyle, la teneur en les motifs d'éther fluorovinylique étant de 15 à 50 mol%.

2. Un procédé de préparation d'un copolymère élastomère contenant du fluor seon la revendication 1, qui consiste à polymériser au moins un éther fluorovinylique avec au moins un autre monomère contenant de fluor.

3. Le procédé selon la revendication 2, dans lequel la polymérisation est effectuée en présence d'une source d'inducteur de polymérisation.